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HARDWALL EXPANDABLE SHELTER

CAPT JOSEPH P. SUGG

DET 1(CEEDO) HQ ADTC
TYNDALL AFB, FL 32403

SEPTEMBER 1977

CEEDO

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TYNDALL AIR FORCE BASE
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The Air Force awarded a contract to Brunswick Corporation for the development of a basic rigid/expandable shelter that would fulfill various user requirements with little or no change in shelter design. Furthermore, the shelter was to be compatible with both air and surface transport criteria. Extensive testing verified that the shelter meets these two basic criteria. However, design details need revision to improve watertightness and reduce shelter gross weight. The Air Force should adopt the hardwall expandable shelter (HES) as a standard for meeting future tactical shelter requirements.

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PREFACE

This report was prepared by Det 1 (CEEDO) HQ ADTC, Tyndall Air Force Base, Florida, under job order 20542002. This report summarizes the work done between April 1973 and August 1977. Captain Joseph Sugg was the project officer. Lieutenant Robert J. Gunning completed the work on the report.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS) where it will be available to the general public including foreign nations.

This technical report has been reviewed and is approved for publication.

ROBERT J. GUNNING, 2d Lt, USAF
Project Officer

GEORGE D. BALLENTINE, Lt Col, USAF
Chief, Airbase Survivability and
Vulnerability Division

GUY P. YORK, Lt Col, USAF
Director of Civil Engineering
Research

JOSEPH S. PIZZUTO, Col, USAF, BSC
Commander

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INTRODUCTION

The increased utilization of air-transportable shelters by the Air Force has resulted in a number of different shelter configurations to house specific systems. The repeated research, development, and testing for each new shelter has been both costly and time consuming for the Air Force. In addition, DOD instruction issued in 1971 stated that future shelters ". . . will conform to ANSI/ISO container specifications to the extent practicable." These two conditions led to the recommendation of the 1972 Mobility Shelter Workshop that a basic rigid/expandable shelter be developed which will fulfill various user requirements with little or no change in shelter design. Furthermore, the shelter must be compatible with both air and surface transport criteria. Table 1 contains a complete list of performance criteria.

In December 1973 the Air Force Civil Engineering Center awarded a contract to Brunswick Corporation for development of the hardwall expandable shelter (HES). This report identifies the shelter requirements, testing to evaluate its capabilities, and recommendations concerning its utilization.

TABLE 1. PERFORMANCE CRITERIA

CRITERIA
Meets air and surface transportability criteria of MIL-A-8421 and ANSI MH 5.1.
Expansion ratio of 7:1.
Erected in 7 manhours.
Erectable on terrain with 18 inch variance over 50 feet.
Excess cargo capacity: 2500 pounds, 550 cubic feet.
Maximum shipping weight, without excess cargo - 9000 pounds.
Overall coefficient of heat transfer - 0.20 $BTU/hr/ft^2/^{0}F$.
30 repetitive erection and striking cycles.
10-year storage life at $-25^{\circ}F$ to $+125^{\circ}F$.
Operational at $-25^{\circ}F$ to $+125^{\circ}F$.
Solar load: $200^{\circ}F$ skin temperature.
Winds of 60 knots gusting to 90 knots.
100 percent relative humidity with condensation.
Watertight.
40 PSF snow load.
Pressure differential to 40,000 feet.
Shelter Base: 463L Interface.

SECTION II

ITEM DESCRIPTION

OVERVIEW

The HES is an 8x8x20 foot container which expands to an 8x20x50 foot shelter (Figures 1 and 2). All components and erection hardware are packed within the container for storage and shipment. Primary components are aluminum skin/honeycomb core composite panels and aluminum extrusions.

CONTAINER

The container portion of the shelter functions as a multi-modal cargo container for shipment of the unit (Figure 3).

All panels utilize 0.040 inch 6061 T-6 aluminum skins hot-bonded to 3.8 pcf Kraft honeycomb core. The floor panel contains a 3 inch core and the end walls contain a 2.5 inch core. All other panels utilize a 2.0 inch core. All cores are impregnated with 1.0 inch of 1.2 pcf foam for added insulation.

Exterior dimensions conform to American National Standard MH5.1, Basic Requirements for Cargo Containers: 96 inches high, 96 inches wide, 238.5 inches long. International Organization for Standardization (ISO) fittings are mounted on each corner (Figure 4). Lower corner fittings are flush with the flat exterior bottom of the shelter and integral rail systems are installed on each side of the shelter base for compatibility with the 463L Cargo Handling System (Figure 5).

The curbside wall of the container is composed of upper and lower hinged panels (Figure 6). In the container mode these panels are interconnected with dual locks and fastened to the side walls with quick disconnect screws. For erection, the panels fold out to form the roof and floor of the interconnect between the container and expanded portion of the shelter.

Hinged side walls fold out and connect to the roof and floor to complete the interconnect (Figure 7). These panels utilize 0.025 inch skins and 2.5 pcf, 2 inch core.

Jack mounts are located at each corner and one endwall contains the power interconnect panel and roof access steps. A 2-foot square aluminum sheet is bonded to the center of the exterior roof skin to provide additional damage resistance from overhead lift slings.

When packed for shipment, approximately 400 cubic feet of excess storage space is located at one end of the shelter and is accessible from the roadside door (Figure 8).

EXPANDED SHELTER

There are 15 basic components that form the expanded portion of the HES. All like components are interchangeable (Figure 9).

A. 2 Container side posts

B. 4 Side posts

C. 2 End posts

D. 2 Container side roof beams

E. 4 Roof beams

F. 2 End roof beams

G. 6 Roof eave panels

H. 3 Roof ridge panels

I. 6 Side panels

J. 1 End panel

K. 1 End panel with double door

L. 9 Floor panels

M. 12 Short floor beams

N. 4 Long floor beams

O. 12 Jacks

Floor panels utilize 3.8 pcf, 2 inch honeycomb core with 0.040 inch interior skin and 0.025 inch exterior skin. All other panels are constructed of 2.5 pcf, 2 inch core and 0.025 inch skins.

Framing members (posts and beams) are interconnected and secured with ball lock pins (Figures 10 and 11). Panels are secured to the framing members and to other panels with dual locks (Figure 12).

The roof ridge panels are hinged at the center to form the peak of the roof and still provide a flat surface for shipment (Figure 13).

The floor jacks are inserted into the long floor beams during erection. The jacks telescope in 4 inch increments to provide three extended jack positions (Figure 14). Adjustment to any position between the 4 inch increments is accomplished from within the shelter by a jack tool inserted through the top of the beam (Figure 15).

Ventilation fans are installed at each end of the HES (Figure 16). Exhaust/return ducts for the environmental control unit (ECU) are installed on the fold-out side panel adjacent to the power input panel.

Power to the HES is supplied through a 120-208 V, 3-phase receptacle in the power input panel. The panel also contains a 208 V, 3-phase receptacle for ECU power (Figure 17).

The power distribution panel on the interior end wall distributes 110 volt power for lighting and wall receptacles. Power to the expanded portion is supplied through exposed wiring and wiring within the posts and beams. All connections utilize class L quick-disconnect hardware.

SECTION III

TESTING

OVERVIEW

Testing was accomplished in three phases to assess the performance of the HES in meeting design criteria and providing a functional facility.

Phase I was accomplished at the Air Force Civil Engineering Center and addressed physical and structural parameters. Phase II was conducted in the climatic laboratory at Eglin AFB to measure the overall U-factor and assess operability at environmental extremes. Phase III involved measuring the performance of the shelter over an extended period of exposure to natural environmental conditions of Tyndall AFB, Florida.

Table 2 lists the testing and overall results. Appendix A contains details of the testing.

TABLE 2. TEST RESULTS

Phase 1	Pass	Fail
Initial Inspection	x	
Erection Time		x
Weight Inspection		x
Ground Transport	x	
Leveling	x	
Electrical	x	
Wind Load	x	
Watertightness		x
Watertightness (Retest)		x
Floor Load	x	
Snow Load	x	
Static Load, Door	x	
Cargo Tie-Down	x	
Wind Load, Door	x	
Racking	x	
Phase 2		
High Temperature Operation	x	
Low Temperature Operation	x	
Heat Transfer		x
Phase 3		
Long Term Use	x	

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

DESIGN CRITIQUE

The following design deficiencies were identified during the testing.

1. Water leakage.

2. Gross weight of shelter is 12,250 pounds. Design goal was 9,000 pounds.

3. Storage space available for excess cargo - 400 cubic feet. Design goal was 550 cubic feet.

4. Normal erection time - 18 manhours. Design goal was 7 manhours.

After reviewing the deficiencies, the contractor submitted a design critique, including recommended design changes for the production model of the HES (Appendix B).

CONCLUSION

1. The HES design fulfills the two primary objectives of the effort:

a. The shelter in the shipping configuration is compatible with surface, ANSI, and 463L/airlift transport criteria.

b. The design provides a high expansion ratio (7:1) and user flexibility in adapting the design to fulfill varying requirements.

2. Design details need revision to improve watertightness and erection time and to decrease gross weight. The contractor's recommended design changes provide acceptable design alternatives for correcting these deficiencies.

RECOMMENDATIONS

1. The design changes recommended herein should be incorporated into future HES production to improve watertightness and erection and to decrease weight of shelter components.

2. The Air Force should adopt the HES as a standard for meeting future tactical shelter requirements. The durability of construction, multi-modal transport capability, and mission flexibility of the HES provide a shelter that will cost-effectively meet Air Force requirements for tactical shelters.

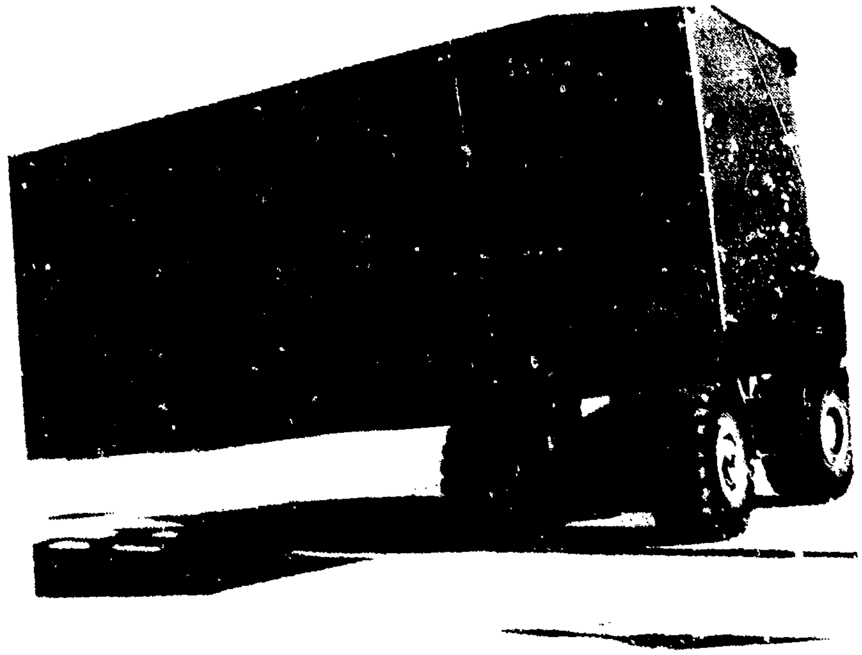

Figure 1. HES in Container Mode

Figure 2. HES in Expanded Mode

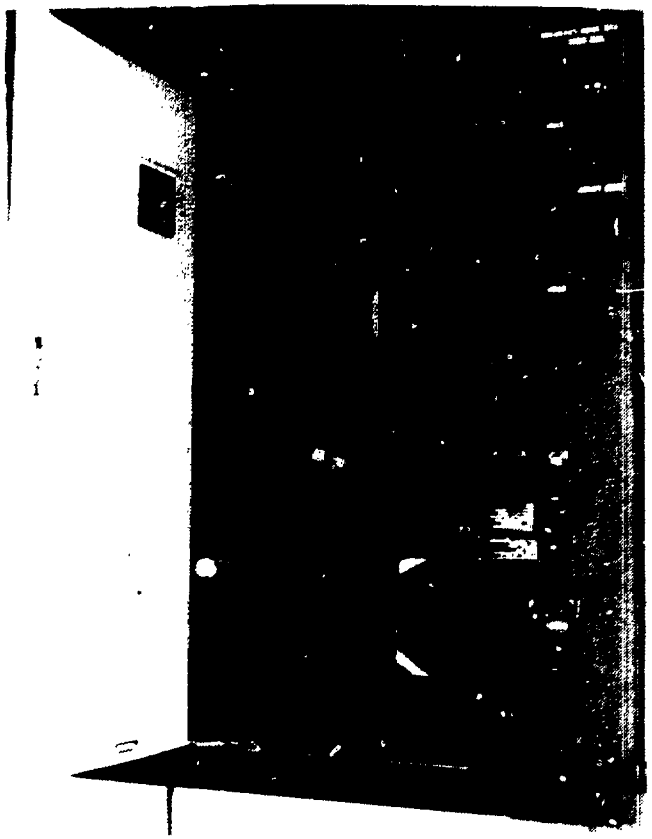

Figure 3. Components Packed in Container

Figure 4. Upper ISO Corner

Figure 5. 463L Interlocks in Container Base

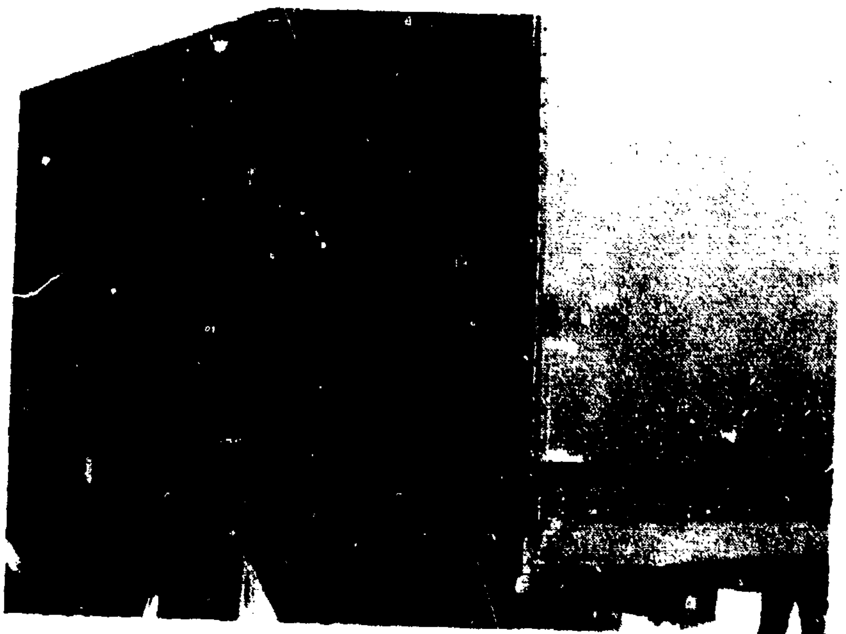

Figure 6. Curbside View of Container Showing Split Sidewall

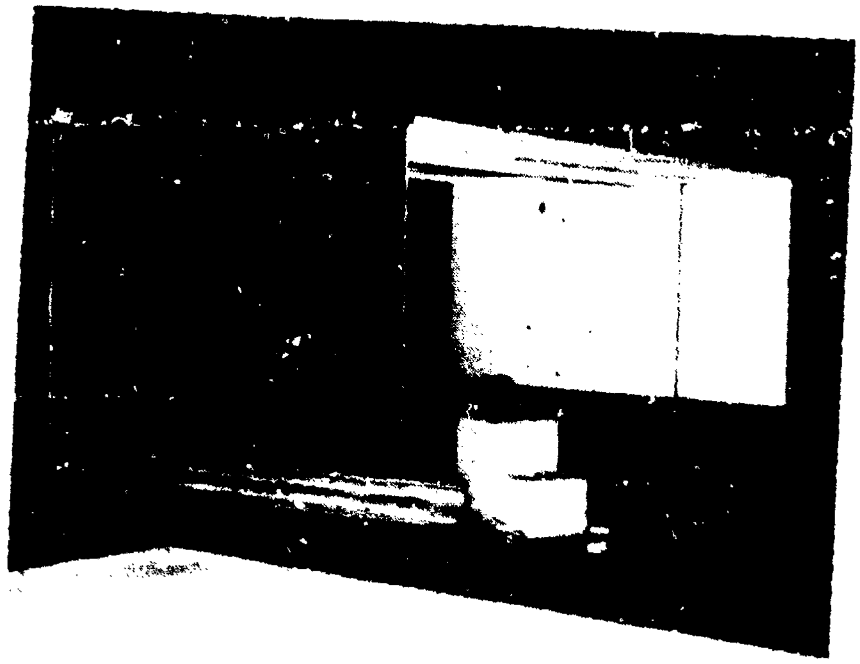

Figure 7. Container Side Opened for Erection

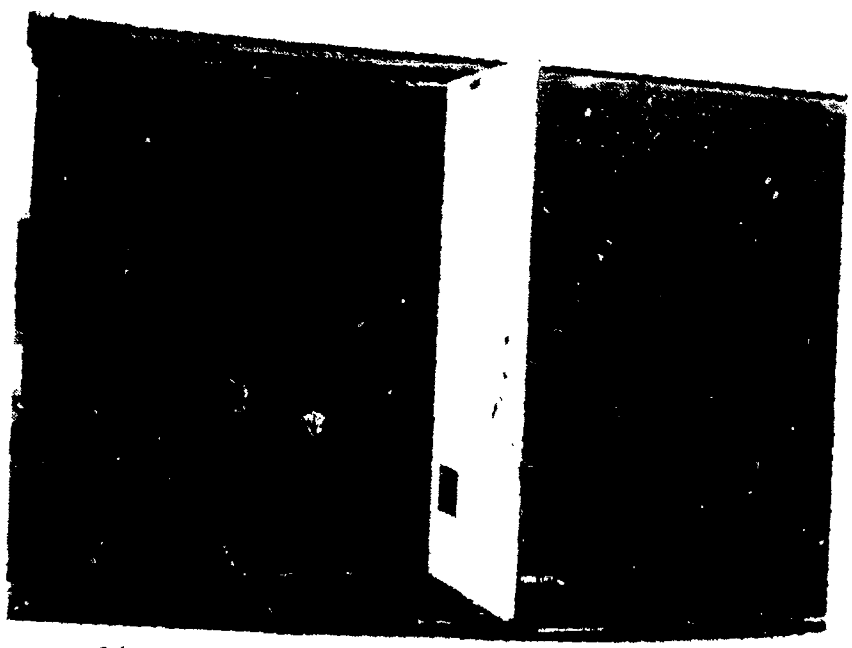

Figure 8. Extra Storage Space in Container

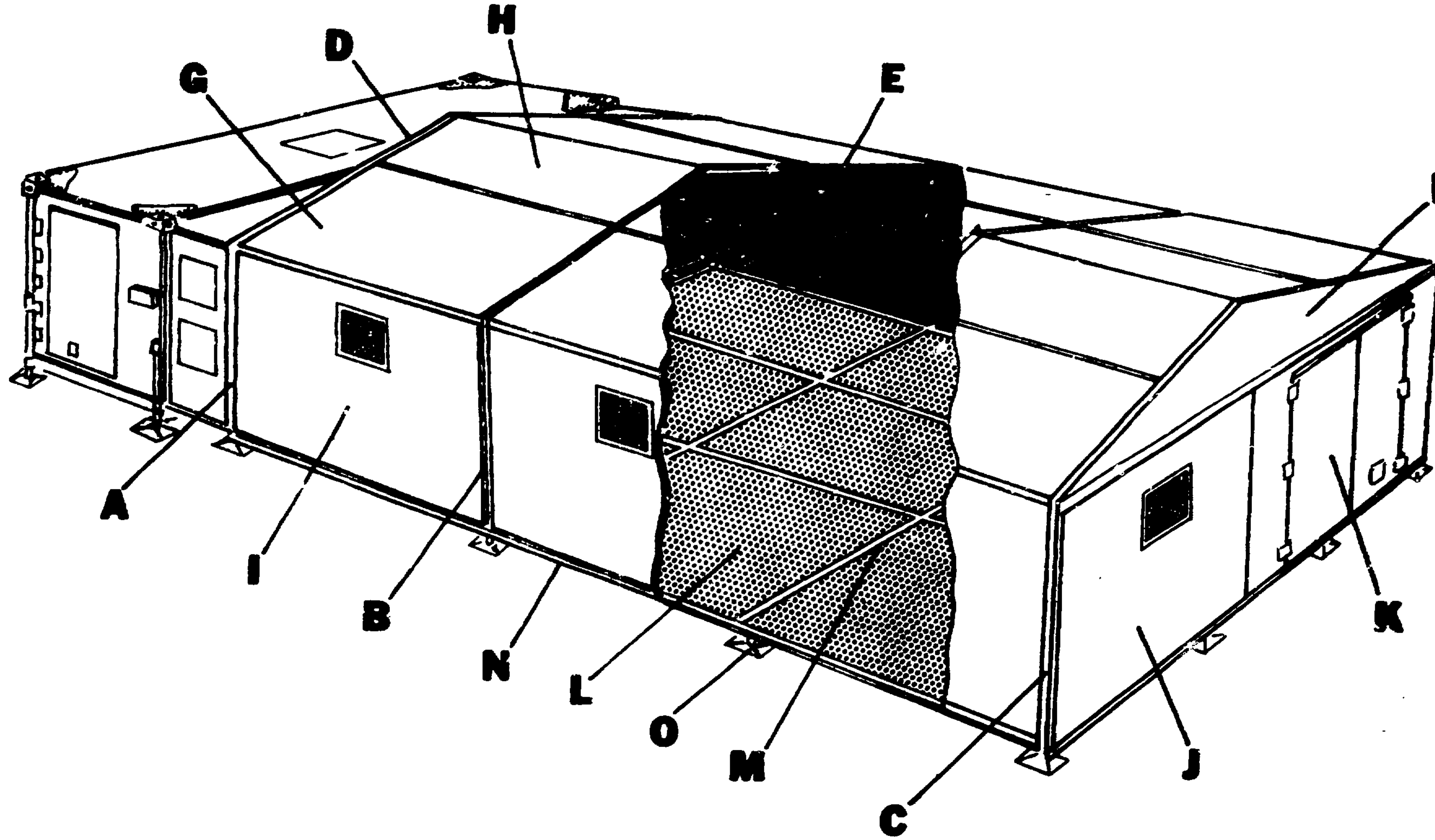

Figure 9. Schematic of Expanded Shelter

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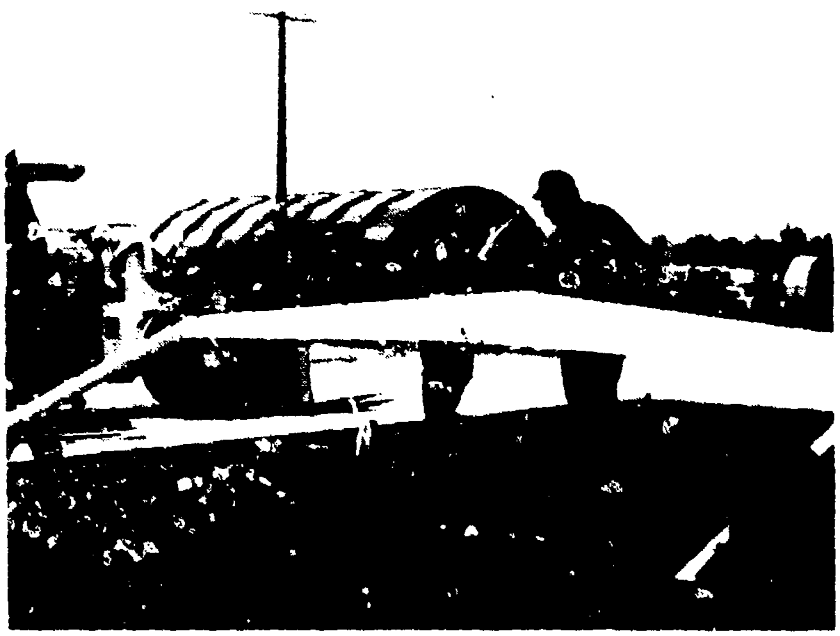

Figure 11. Assembled Arch Being Erected

Figure 12. Dual Locks Interlock Panels

Figure 13. Hinged Roof Ridge Panel Being Installed

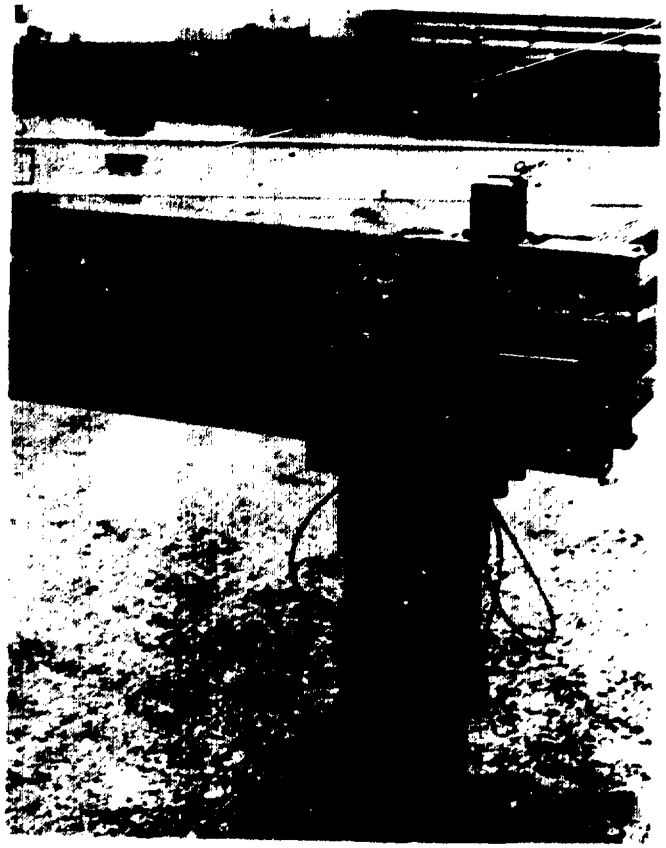

Figure 14. Extended Leveling Jack

Figure 15. Adjusting Leveling Jack

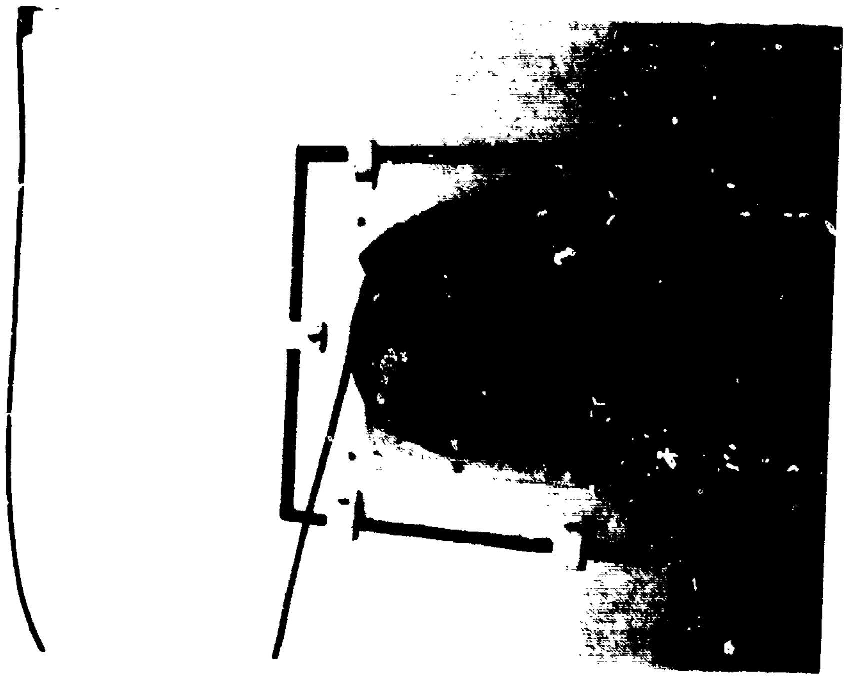

Figure 16. Ventilation Fan

Figure 17. Power Input Panel

APPENDIX A

TESTING DETAILS

PHASE I

The shelter was delivered to AFCEC from the contractor's plant in Marion, VA by a Brunswick truck on 17 Jan 75 (Figure 6). Phase I testing was conducted between January and June 1975.

Initial Inspection

Objective. To verify that the HES was received in a satisfactory condition.

Procedure. Unpack container and inventory. Examine components for physical damage and inspect panels for delaminations and presence of water.

Results

a. The shelter was unloaded from the Brunswick vehicle by forklift and positioned on the ground. Racking caused by the uneven terrain induced shear loads on the quick disconnect screws and dual locks which precluded opening the curbside wall. The container jacks were removed and installed to level the container. During this operation two jacks failed. One handle sheared off at the worm gear and the other jack jammed (Figure A-1). Leveling was accomplished with the aid of a forklift and the side wall fasteners were released.

b. Shelter components were removed, visually inspected, and inventoried. No damage was noted but the repair kit and components of the tool kit were missing.

c. Using an eddy sonic nondestructive inspection (NDI) device, panels were inspected for delaminations and presence of water within the panel (Figure A-2). Container, floor, and roof ridge panels were fully bonded with no water present. Two small delaminations were located on one roof eave panel. Three small delaminations were located on one side panel and one panel contained a 2-inch wide by 3-foot long delamination.

d. Excessive dunnage was required for packing the side panels. The window hinges protruded outside the plane of the panel surface, requiring 1x4's to separate the panels when stacked in the container.

Weight Inspection

Objective. To determine the weight of the shelter in the shipping mode.

Procedure. Using WEBB scales, weigh the vehicle on which the HES will be transported. Position the HES on the vehicle and reweigh the loaded vehicle.

Results.

Weight of vehicle, with shelter	52,820 lb
Weight of vehicle, empty	40,670 lb
	12,150 lb

Ground Transportation Test

Objective. To verify that the HES in the shipping configuration will withstand the loadings associated with ground vehicle transportation tests specified in the HES specification.

Procedures. Mount and secure the HES, fully loaded, on a semi-truck trailer and traverse the various types of road surfaces as specified in Table A-1. At the conclusion of each test the HES was removed from the trailer and inspected for any damage. Recording accelerometers were attached to the HES to measure G-loading during the tests (Figures A-3, A-4, A-5).

TABLE A-1. GROUND TRANSPORTATION TESTS

Road Type	Avg Speed (mph)	Max Speed (mph)	Distance (miles)
Hard Surface Highway	50	55	100
Gravel Road	20	25	50
Cross Country	15	20	10

Results

a. No damage was noted as a result of the test.

b. Maximum recorded loadings are shown in Table A-2.

TABLE A-2. TRANSPORTATION TEST G-LOADS

Road Type	Distance	Loading* Vertical	Fore/Aft	Traverse
Hard Surface	100	± 2G	±1.5G	± 1G
Gravel	50	± 4G	± 2G	± 1.5G
Cross Country	10	± 4G	± 4G	± 1G

*Recorder reads "0" at start of test

Leveling Demonstration

Objective. To verify that the shelter can be leveled on a longitudinal grade of 3 percent.

Procedure. Erect the shelter on terrain which varies 18 inches over 50 feet. After erection ascertain that both container and floor beam jacks can be adjusted to compensate for settling (Figure A-6).

Results

a. The shelter was erected on a sand and shell test site which had been surveyed and graded to obtain the 3 percent grade. New, higher quality container jacks had been received from Brunswick and the entire shelter was leveled on the test site.

b. Floor beam jacks were adjustable from the interior of the shelter. However, the tool provided was awkward to use. An improved jack tool was fabricated that could be utilized with a speed wrench and worked extremely well.

Electrical Test

Objective. To verify electrical readiness of the shelter.

Procedure. Verify continuity of circuits of the electrical distribution system. Operate all lights and electrically powered equipment.

Results

a. No deficiencies were noted.

b. Power to the shelter was supplied with a bare base connector and 50 feet of 5-wire cable.

Watertightness Test

Objective. To verify the watertightness of the HES in both the erected and shipping modes.

Procedure. Apply 60 mph wind with simulated rain to each side of the shelter in both the erected and shipping modes.

Test Equipment. The wind generator is shown in Figure A-7. Fan speed is a function of engine rpm. An anemometer was used to calibrate the machine for a wind velocity of 70 mph at a distance of 15 feet. A spray bar attached to the front of the wind machine provided the simulated rain.

Results

a. Figures A-8 through A-11 depict leaks observed during simulated rain with 70 mph wind for 8 minutes on each vertical panel.

Watertightness Retest

Modifications

The following modifications were accomplished by the contractor to improve watertightness.

a. Installed an additional gasket around both doors. The cargo doors in the expanded end wall leaked around the frame. The door frame and door edge extrusions had provisions for four gaskets, but only two were originally installed.

b. All windows were removed and 0.090 inch thick phenolic shim removed from under the hinge. The shim prevented the window frame from correctly seating on the window gasket (Figure A-12).

c. Sealed mitered corners and along edges of window with RTU.

Retest

The modifications were successful in preventing leaks around doors and windows. However, leaks at upper curbside ISO fittings and several panel-to-panel seals could only be stopped by taping the joi.. s with tape and installing covers over the ISO corners (Figure A-13). Design changes will be required to improve watertightness of these areas.

Floor Load Test

Objectives. To verify that the shelter in the erected mode can withstand:

a. Floor load of 80 lb/ft^2 over expanded floor.

b. Floor load of 85 lb/ft^2 over container floor.

Procedure. Uniform loads were obtained with 40-pound bags of sand. The floor was divided into 2 foot stations. Readings were taken at each station before loading and after load had been applied for 2 hours (Figure A-14).

Results. Deflection due to the loading was minimal. No structural damage or permanent deformation was incurred as a result of the tests.

Roof Load Test

Objective. To verify that the shelter can withstand a roof load of 40 lb/ft^2.

Procedure. Elevation readings were taken at two-foot stations. Approximately one half of the expanded roof section was loaded to 40 lb/ft^2 with 40-pound sand bags and left overnight. Roof loading was completed the following day and readings taken at each station (Figure A-15).

Results. Minimum deflection was observed with no structural damage or permanent deformation.

Static Load Test, Doors

Objective. To ascertain the ability of the door to sustain vertical loads.

Procedure. The door was opened to 90 degrees from the plane of the sidewall and a 200-pound load was applied to the door at a point 30 inches from the hinge (Figure A-16).

Results. The load was removed after 30 minutes. No damage was noted and the door continued to function normally.

Tie-Down Test

Objective. To verify that the cargo container tie-downs can withstand a direct tensile load of 2000 pounds.

Procedure. Load was applied to the tie-down using the cargo straps and connection hardware supplied with the HES. Figure A-17 shows how

the load was obtained using a come-along and forklift tine for bracing. Load was measured by a tensiometer cylinder between the come-along strap and the tie-down strap. The load was applied in two increments: rapid loading to 1500 pounds, then gradually increasing the load to 2000 pounds.

Results. Two floor tie-downs were tested. No distortion or evidence of failure was noted in either test.

Simulated Wind Gust, Doors

Objective. To ascertain the ability of the doors to sustain winds without damage.

Procedure. The roadside container door was opened 100 degrees to the stop. Using the wind machine, a 60 mph wind load was applied perpendicular to the face of the door for 2 minutes (Figure A-18).

Results. No evidence of distortion, damage, deformation, or misalignment was noted and the door functioned normally after the test.

Longitudinal Restraint Test

Objective. To ascertain the fore/aft restraint capability of the lower ISO corner fittings.

Procedure. In the shipping configuration, fully loaded, the container was restrained by securing the bottom corner fittings at one end. A 30,000-pound load was longitudinally applied to the bottom corner fittings at the opposite end, first in tension, then compression. Load was applied in 5000 pound increments using a hydraulic ram (Figure A-19).

Result. No permanent deformation or damage was noted.

Racking Test

<u>Objective</u>. To verify the ability of the container to withstand racking loads associated with container ship transport.

<u>Procedure</u>. The container, fully loaded in the shipping configuration, was secured by all four bottom corner fittings.

a. <u>Lateral Test</u>. A total load of 33,600 pounds was applied to one top corner fitting with a line of action of the load horizontal and parallel to the end of the container (Figures A-20 and A-21).

b. <u>Longitudinal Test</u>. A total load of 33,600 pounds was applied to another top corner fitting with a line of action of the load horizontal and parallel to the side of the container.

c. Loading was applied using a hydraulic ram and load gauge to an estimated value of 33,000 pounds.

d. Bottom corner fittings were secured by inserting steel rods into corner fittings and anchoring with heavy equipment.

<u>Result</u>

a. <u>Lateral Test</u>. Loaded top ISO fitting deflected 0.50 inch under load and rebounded to 0-inch deflection when load was removed.

b. <u>Longitudinal Test</u>. Loaded top ISO fitting deflected 0.375 inch under load and rebounded 0-inch deflection when load was removed.

c. Following the test, the hydraulic gauge was calibrated. Actual load applied was 57,300 pounds.

The shelter was transported by lowboy to the Climatic Laboratory for testing 17 July - 6 August 75. Tests were to assess operability of the shelter at high and low temperature extremes (MIL-STD-810) and determine the overall coefficient of heat transfer of the shelter. Before beginning the tests the shelter was unloaded, erected, and dismantled at 60°F to insure no damage was incurred during transit.

High Temperature Test. (Figure A-22)

With the shelter unpacked and completely disassembled, the temperature was raised to 125°F and 154°F, then stabilized at 125°F.

Erection at 125°F began 21 July by a seven-man crew. Assembly of the shelter was completed in 9 hours elapsed time. Maximum time for working in the high temperature was approximately 20 minutes with an equal break time. In addition a 1-hour break was taken. One crew member showed signs of heat exhaustion after 2 hours and was not allowed to continue the test. Total manhours actually expended:

Crew Members	Hours
A	4
B	4
C	4
D	4
E	4
F	4
G	1
	25 manhours

Shelter striking required 3 hours with the same work/test intervals as erection total manhours:

7 x 1.5 = 10.5 manhours

After striking, the chamber temperature was lowered to 60°F and maintained for 14 hours. The shelter was then erected as a quality check. Erection required 3.5 hours with two 15-minute breaks.

$$3 \times 7 = 21 \text{ manhours}$$

Observations

1. Fit of components was not adversely affected by the high temperature.

2. Personnel were less than 50 percent effective when working in the high temperature environment.

3. Assembly problems after cool down were encountered due to bowing of panels. This was caused by the delay in cool down of the hangar's concrete floor.

4. No material degradation or mechanical problems were noted as a result of the high temperature testing.

Heat Transfer

With the shelter erected and temperature at 60°F, 36 thermocouples were installed on interior and exterior surfaces of the HES (Figures A-23 and A-24). Nine heater blowers to be used in the test were calibrated to determine total current required to operate the heaters at full capacity. Using a design U-factor of 0.30, it was estimated that 26 kw would be required to maintain a differential of 100°F between inner and outer air temperatures. Upper and lower thermocouples were mounted to the facing of the panels. The middle thermocouples were mounted 6-inches from the skin.

At 1500 hours 24 July the temperature was lowered to -25°F within 1 hour and maintained.

At 0700 hours 25 July heaters were installed and recording equipment was checked operational (Figure A-25). At 1500 hours the heaters were turned on and temperature lowered to -40°F and maintained. Readings were taken every 6 hours until 0600 28 July. At 1500 the temperature was raised to 60°F and maintained overnight.

On 29 July the shelter was disassembled and inspected for damage. Components were functional; however, some degradation was noted where seals had started delaminating (Figure A-26). At 1500 hours the temperature was lowered to -25°F and maintained.

On 30 July the shelter was erected at -25°F (Figure A-27). The crew wore arctic clothing and were able to work 50 minutes and rest 10 minutes. Total elapsed time for erection was 3.5 hours. The crew stated that assembly of components was easiest at the cold temperature. At 1600 hours the temperature was raised to 40°F. This was to stabilize skin temperature above freezing for installation of thermocouples for second heat transfer test.

At 1700 hours 31 July installation of equipment began for the second heat transfer test. Thermocouples were installed as in the first test and circuits checked for continuity. All joints were taped (Figure A-28). The purpose of the taping was to evaluate its use in cold temperatures and to determine its merit as both an insulator and sealant.

At 1500 hours the heaters were turned on and temperature lowered to -40°F. Readings were taken every 6 hours until 3 August. Temperatures had stabilized for wall test and chamber temperature was raised to -20°F and maintained. On 4 August the shelter was disassembled and the temperature was then raised to ambient.

On 5 August all components were inspected and packed and the HES returned to Tyndall AFB by lowboy.

CONCLUSIONS

1. The shelter can be erected, disassembled, and operational in temperatures between -25°F and +125°F. In addition environmental extremes of -40°F and +125°F do not adversely affect the erected shelter. Erection and striking times at environmental extremes are extended due to the limitations of the crew to work in these environemnts.

2. Overall U-factor of the shelter as built was 0.34.

3. With tape installed, U-factor was reduced to 0.23.

PHASE III

After completion of the environmental tests the HES was returned to Tyndall AFB and erected for the long term test. During the past 2 years it has been used to house supplies, a water biology laboratory, a workshop (drill press, band saw, etc) and a chemistry laboratory. The shelter survived hurricane Eloise without damage (Figures A-29 and A-30).

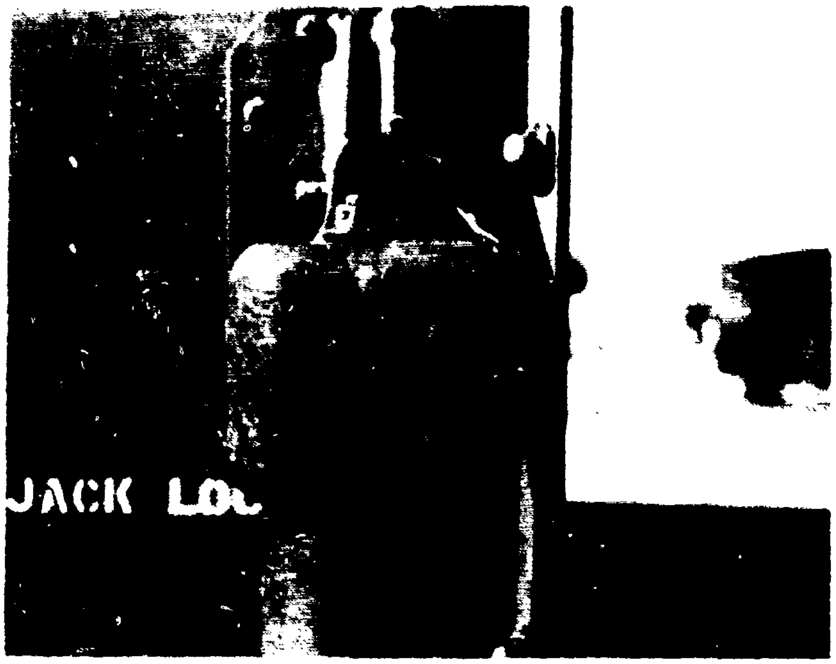

Figure A-1. Container Jack Failure


Figure A-2. Checking Panels for Debond

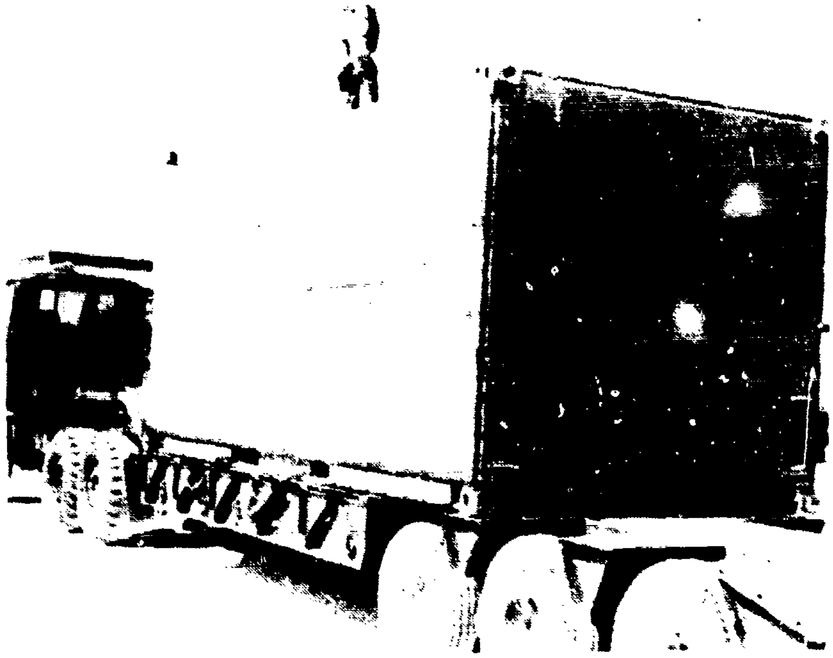

Figure A-3. HES Loaded for Transport Test

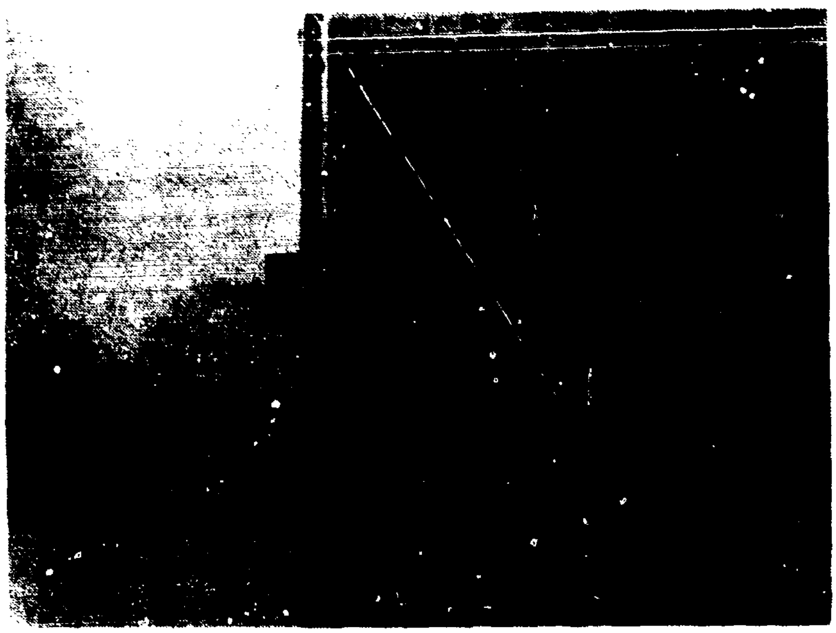

Figure A-4. Acceleromenter Mounted on End Wall

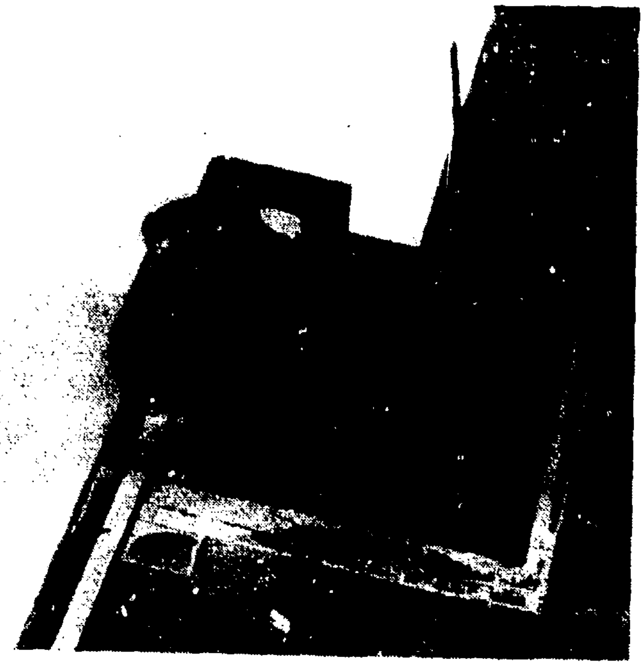

Figure A-5. Accelerommenter Mounted on Roof

Figure A-6. Shelter Floor Leveled on 3 Percent Slope

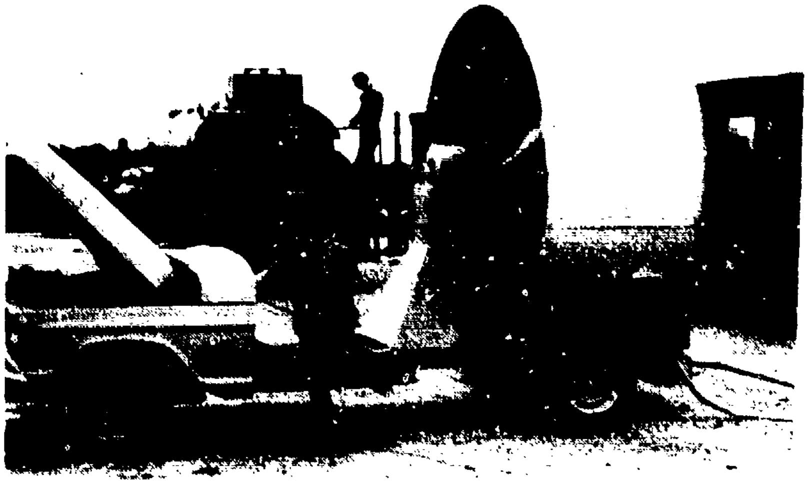

Figure A-7. Wind Machine

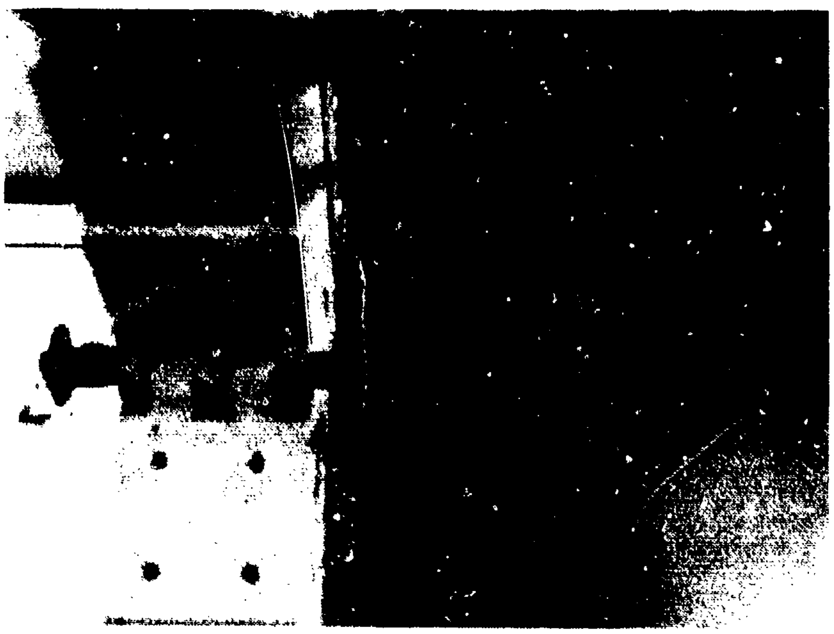

Figure A-8. Leak at Wall/Column/Roof Joint

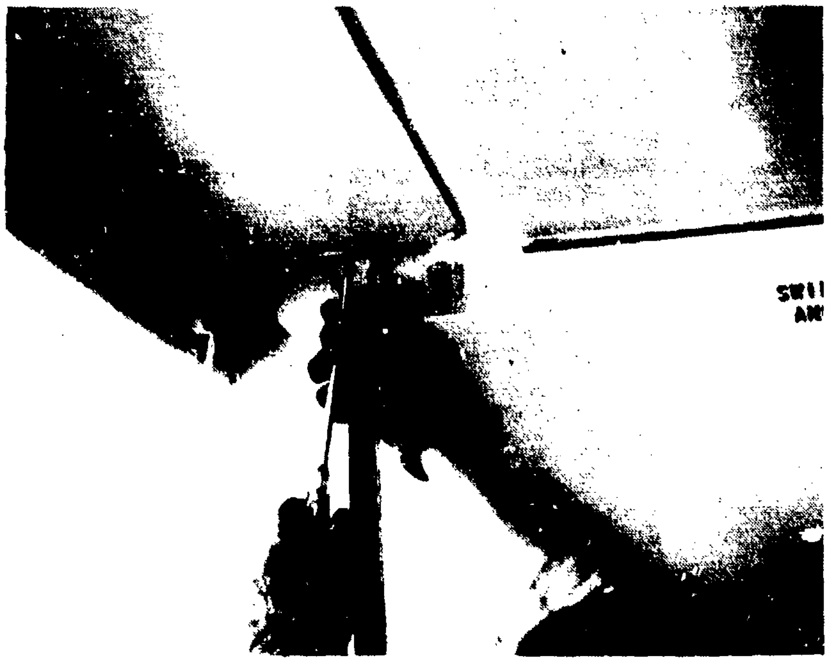

Figure A-9. Leak Through Gap Between Fold-Out Side Panel and ISO F

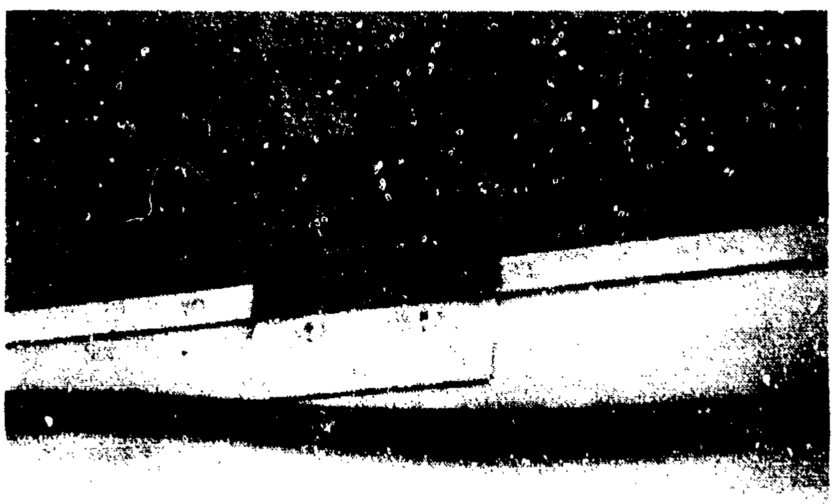

Figure A-10. Leak Through Wall/Roof Dual Lock

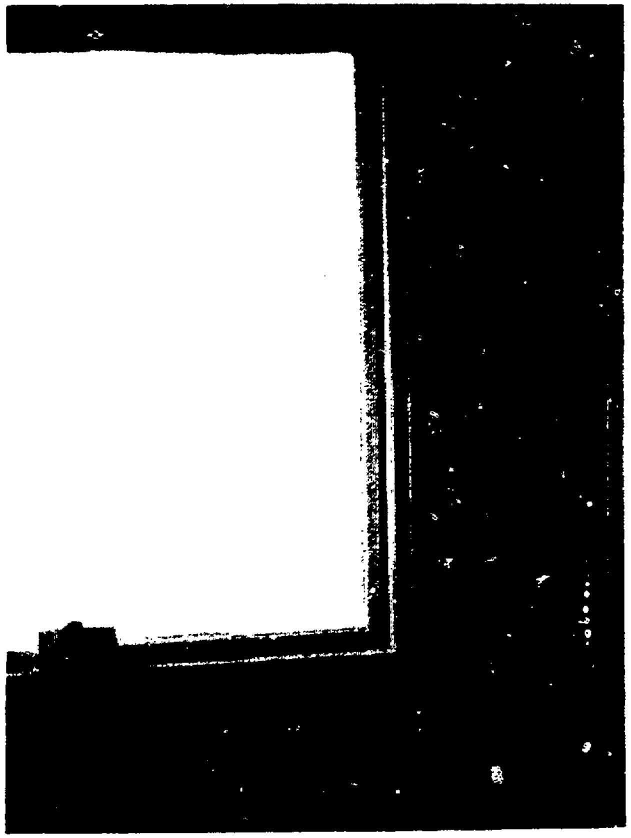

Figure A-11. Typical Window Leak

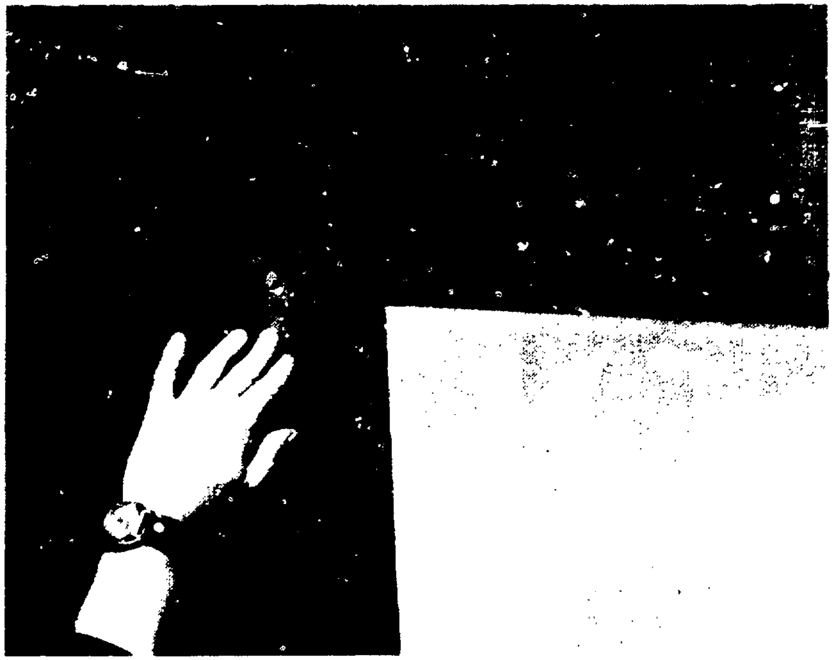

Figure A-12. Shim Removed from Window Hinges

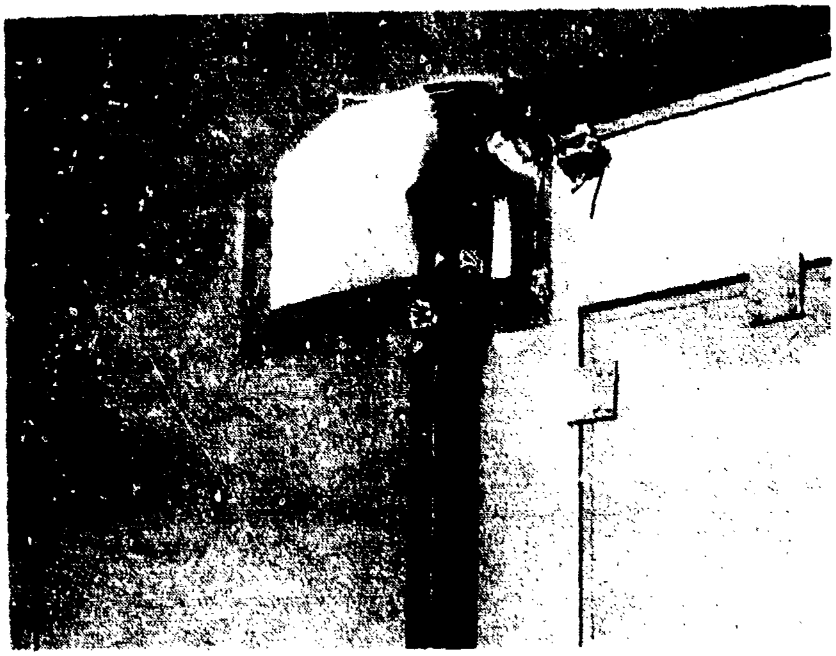

Figure A-13. Cover Over Upper ISO Corner

Figure A-14. Sandbags Being Placed on Container Floor

Figure A-15. Simulated Snow Load Test

Figure A-16. Static Door Load Test

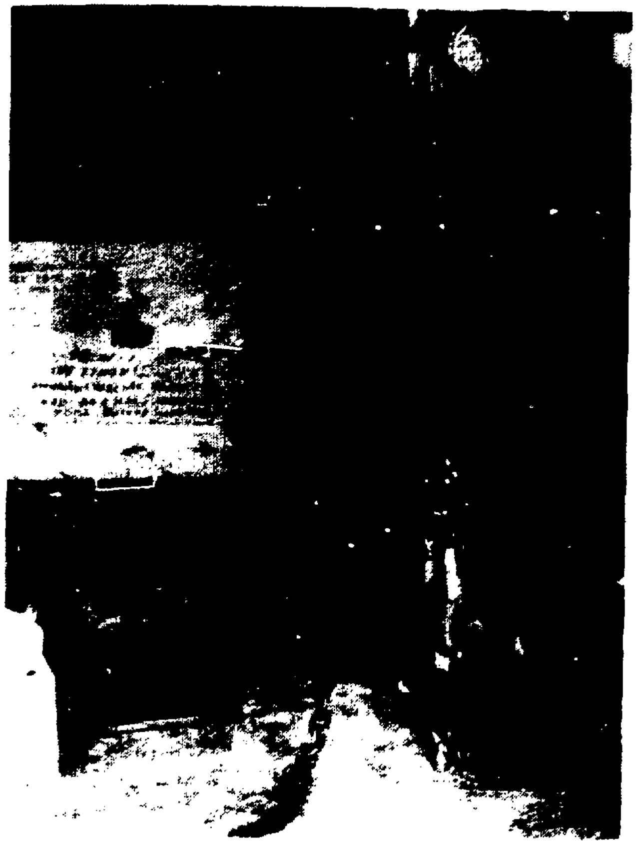

Figure A-17. Tie-Down Test

Figure A-18. Door Open in 60 mph Wind

Figure A-19. Longitudinal Restraint Test

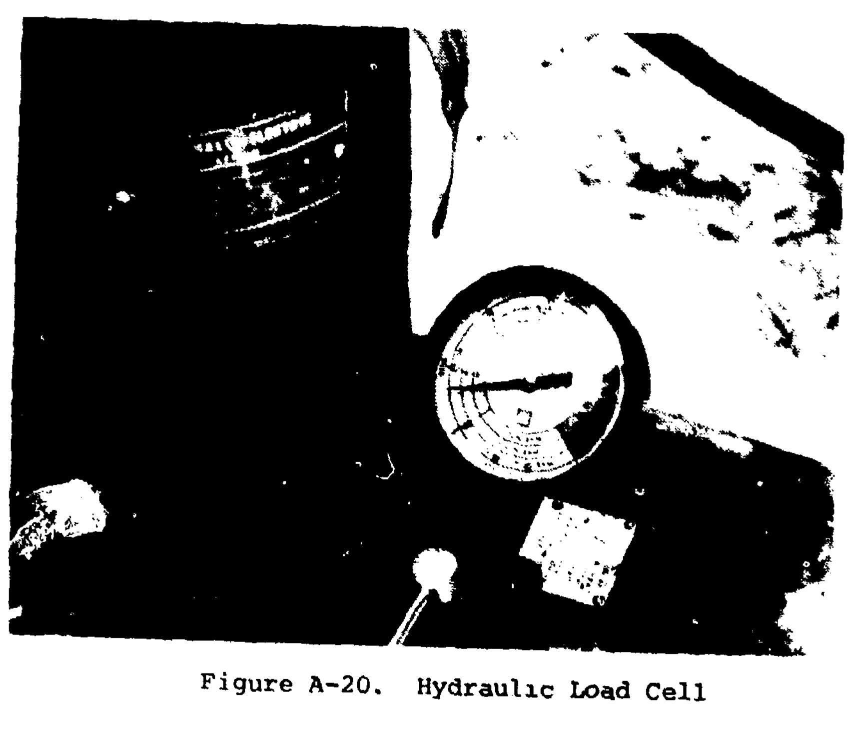

Figure A-20. Hydraulic Load Cell

Figure A-21. Lateral Racking Test

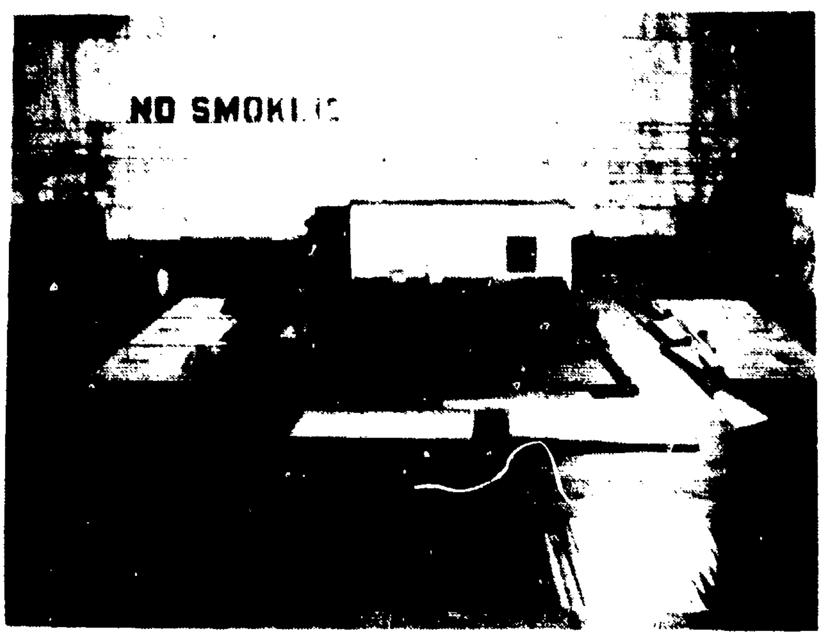

Figure A-22. HES Unpacked in Climatic Lab

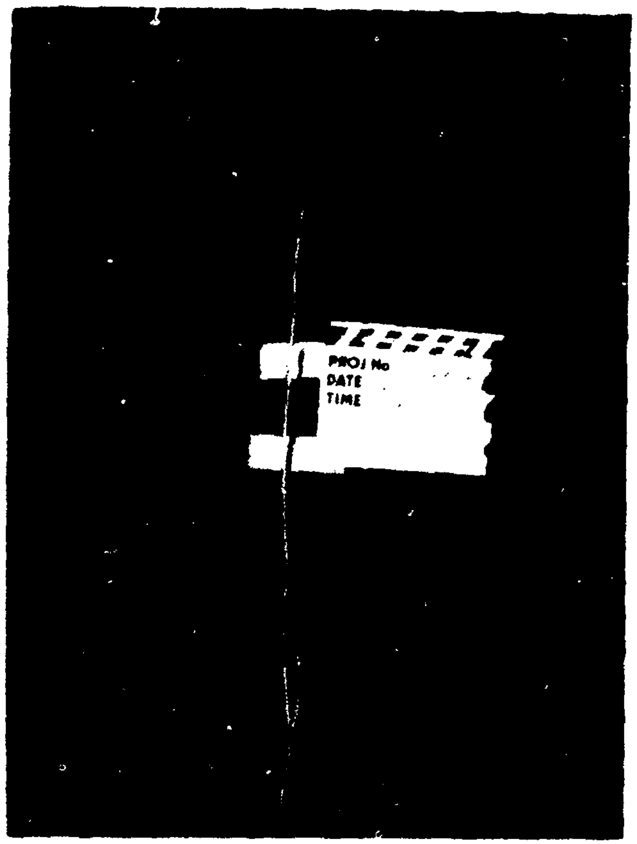

Figure A-23. Typical Theromocouple

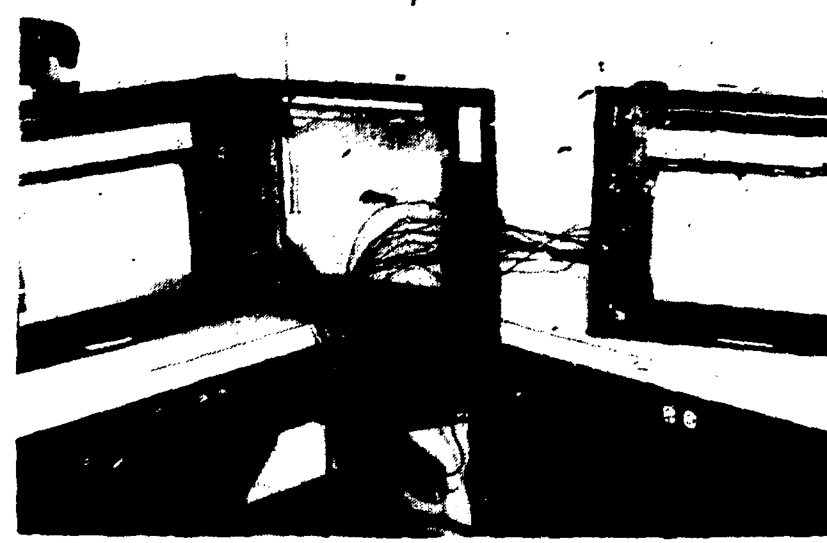

Figure A-24. Temperature Recorders

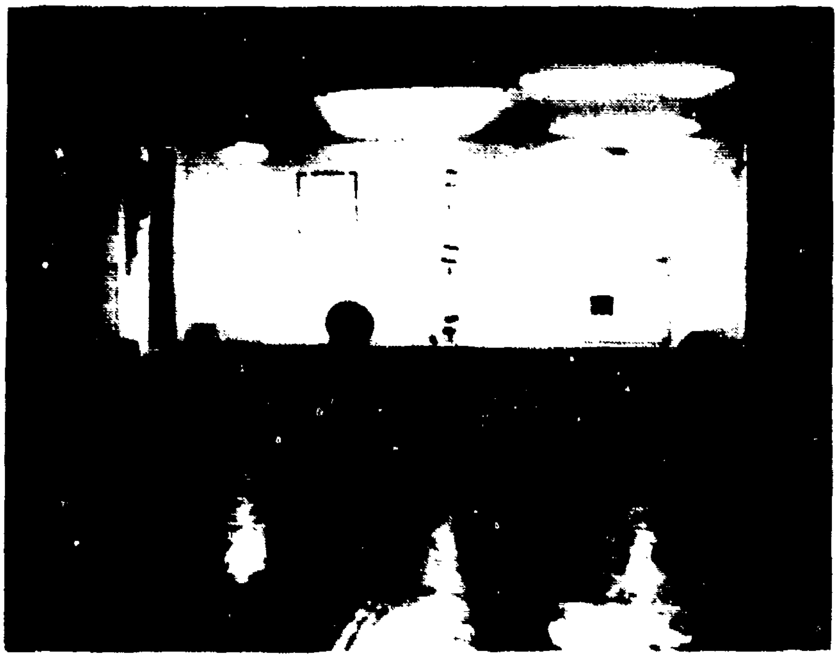

Figure A-25. Heater Placement Within Shelter

Figure A-26. Seal Delamination on Roof Ridge Panel

Figure A-27. Low Temperature Erection

Figure A-28. Taped Joint

Figure A-29. HES at Tyndall AFB

Figure A-30. Interior of HES at Tyndall AFB

APPENDIX B

DESIGN CRITIQUE HES 7 FOR 1 SHELTER

INTRODUCTION

In compliance with Amendment No. P00004, Contract No. F08638-74-C-0003, dated 15 April 1975, Brunswick is submitting a general design critique of the HES 7 for 1 Shelter which includes:

- Weight analysis of present prototype design.
- Proposed changes for a production shelter design to improve watertightness, reduce weight and erection time, and improve packaging.
- Weight analysis of proposed production design.
- Production cost estimates, with quantity price breaks identified, for the production design.

WEIGHT ANALYSIS

The calculated weight is 11,530 pounds. The actual weight as weighed at Tyndall was 12,150 pounds. The difference could be accounted for by tolerance of aluminum elements which may be on the high side, other changes and generous use of epoxy resin for potting inserts, etc. These materials are normally better controlled in a production design.

The calculated weight of the container section which included the weight of jacks is 3389 pounds. This compares very closely with the empty weight (without jacks) of 3240 pounds as weighed at Tyndall.

STORAGE SPACE

Neither the storage space requirement nor the packaging method can be changed much for the prototype design. The packaging method has been described in Section VII of the Technical Manual, Hardwall Expandable Shelter (HES), dated 15 January 1975.

With a reduction in storage space required for packaging the shelter elements for the proposed product design, considerable improvement can be effected in the packaging methods which will reduce erection and striking time for the shelter.

ERECTION ANALYSIS

The Erection Manual referenced previously describes safety precautions and erection procedures for the shelter. Using these procedures, the shelter can be erected as demonstrated at Tyndall in approximately 18 manhours. The production shelter should be erected in less than 15 manhours using much the same procedures.

RECOMMENDED DESIGN CHANGES

If suggested changes can be effected in a production HES 7 for 1 shelter design, the purpose of the prototype shelter will be achieved. Changes are suggested which will reduce weight and improve performance of the shelter, particularly in the areas of sealing for watertightness, erection and packaging. Proposed changes will also result in lower costs for a production shelter.

Brunswick believes that the proposed HES Shelter will be an advancement of the state-of-the-art shelter designs and will be most useful for many Air Force and Tri-Service Programs. Several changes are suggested:

1. Eliminate the flat bottom requirement and the 463L locking rails to permit simple base framing. If this change is made, weight reduction would be approximately 660 pounds and cost savings per shelter system would be over $1500.

2. Load and secure the shelter to two 463L standard pallets which are available at any Air Force cargo depot. This has been the normal way of loading shelters in a C-130 or equivalent aircraft.

3. Change the container design to eliminate leakage at the upper ISO corner fittings and simplify erection procedures. Lowering the roof hinge line will eliminate the necessity of notching the hinge walls around the top ISO fittings.

4. Eliminate ISO requirements, if possible, simplify design, eliminate sealing problems at ISO upper corner fittings and reduce weight and costs. This change is not contemplated in the proposed changes, but should be considered by the Procuring Agency depending on the mission of the shelter.

5. Change the modular section of the shelter to include:

a. Reduced thickness of wall and roof panels. Panels are stiffer than need be for design loads. Panel thickness would be reduced to 1.58 from 2.08. This change will reduce weight slightly but more important, will greatly simplify packaging by reducing cube requirements a minimum of 90 cubic feet.

b. Simplified roof beam and post design to reduce costs of fabrication, weight and cube requirements for packaging.

c. Changed floor beam design to reflect realistic floor loads. Beams have been over-designed for stiffness under maximum loading conditions for any one beam. This change reduces weights, costs, and packaging cube.

d. Changed panel sealing of roof and wall panels to improve sealing technique and to allow greater tolerance in erection. This change will speed the erection sequence.

Taken together, all suggested changes will reduce weight, lower costs, and improve performance of the HES shelter as follows:

1. Production costs in quantities of 100 or more will be reduced a minimum of $5000 each. Greater proportionate cost reduction for smaller quantities is given.

2. Sealing will be greatly improved.

3. Packaging cube will be reduced a minimum of 130 cubic feet resulting in more foolproof packaging procedures.

4. Erection and striking times will be reduced primarily due to larger tolerance fit in wall, roof, and floor panels and simplify packaging methods.

5. Reliability of the shelter system will be improved.

6. The proposed shelter will have a useful life in excess of 10 years and will be reasonable in cost for production quantities.

7. The proposed changes for a production shelter will reduce weight approximately 2000 pounds.

HES PRODUCTION COSTS

The following costs have been established for limited and full production of the redesigned HES:

Quantity	Unit Price
10	$ 84,000
20	68,250
50	59,250
100	52,750

The values include hard tooling for economical production. In quantities below ten, temporary soft tooling would be recommended. Any order would include data, manuals, etc. at a price to be negotiated.

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HQ USAF/PREC	1
HQ USAF/PREEO	1
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Dir, Waterways Experiment Station	1
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